United States Patent [19]

Sasaki et al.

[11] **3,813,767**

[45] **June 4, 1974**

[54] **METHOD OF MANUFACTURE OF ANNULAR MAGNETIC CORES**

[75] Inventors: **Hajime Sasaki; Kazuo Yamagishi; Sukeyoshi Sakai,** all of Yokohama; **Toshihiro Hoshi,** Kawasaki, all of Japan

[73] Assignee: **Fujitsu Limited,** Kawasaki, Japan

[22] Filed: **July 21, 1971**

[21] Appl. No.: **164,891**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 755,368, Aug. 26, 1968.

[30] **Foreign Application Priority Data**

Aug. 28, 1967 Japan 42-55427

[52] **U.S. Cl.** .... 29/604, 29/417, 29/423, 264/272, 264/317, 340/174 PW

[51] **Int. Cl.** **H01f 7/06**

[58] **Field of Search** .... 29/604, 417, 423; 340/174 PW, 174 MS; 264/317, 272

[56] **References Cited**

UNITED STATES PATENTS

2,877,540	3/1959	Austen	29/604
3,183,567	5/1965	Riseman et al.	29/604
3,325,881	6/1967	Engelking	29/423 X
3,392,441	7/1968	Bartkus et al.	29/604
3,536,800	10/1970	Hubbard	264/317 X

FOREIGN PATENTS OR APPLICATIONS

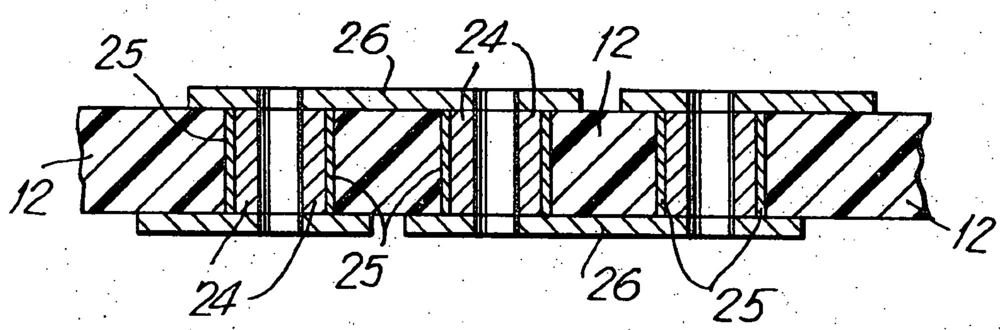
833,958	5/1960	Great Britain	29/604

Primary Examiner—Charles W. Lanham
Assistant Examiner—Carl E. Hall
Attorney, Agent, or Firm—Curt M. Avery et al.

[57] **ABSTRACT**

A plurality of core wires each covered by a layer of magnetic material are positioned in a desired arrangement relative to each other. The arrangement of covered core wires is embedded in molding material. The molding material is hardened to firmly affix the covered core wires in their arranged positions. A section of the molded arrangement of covered wires is removed at substantially right angles to the axes of the wires. Each of the core wires is then removed from the section and the layer of magnetic material of each is retained in the section.

7 Claims, 20 Drawing Figures



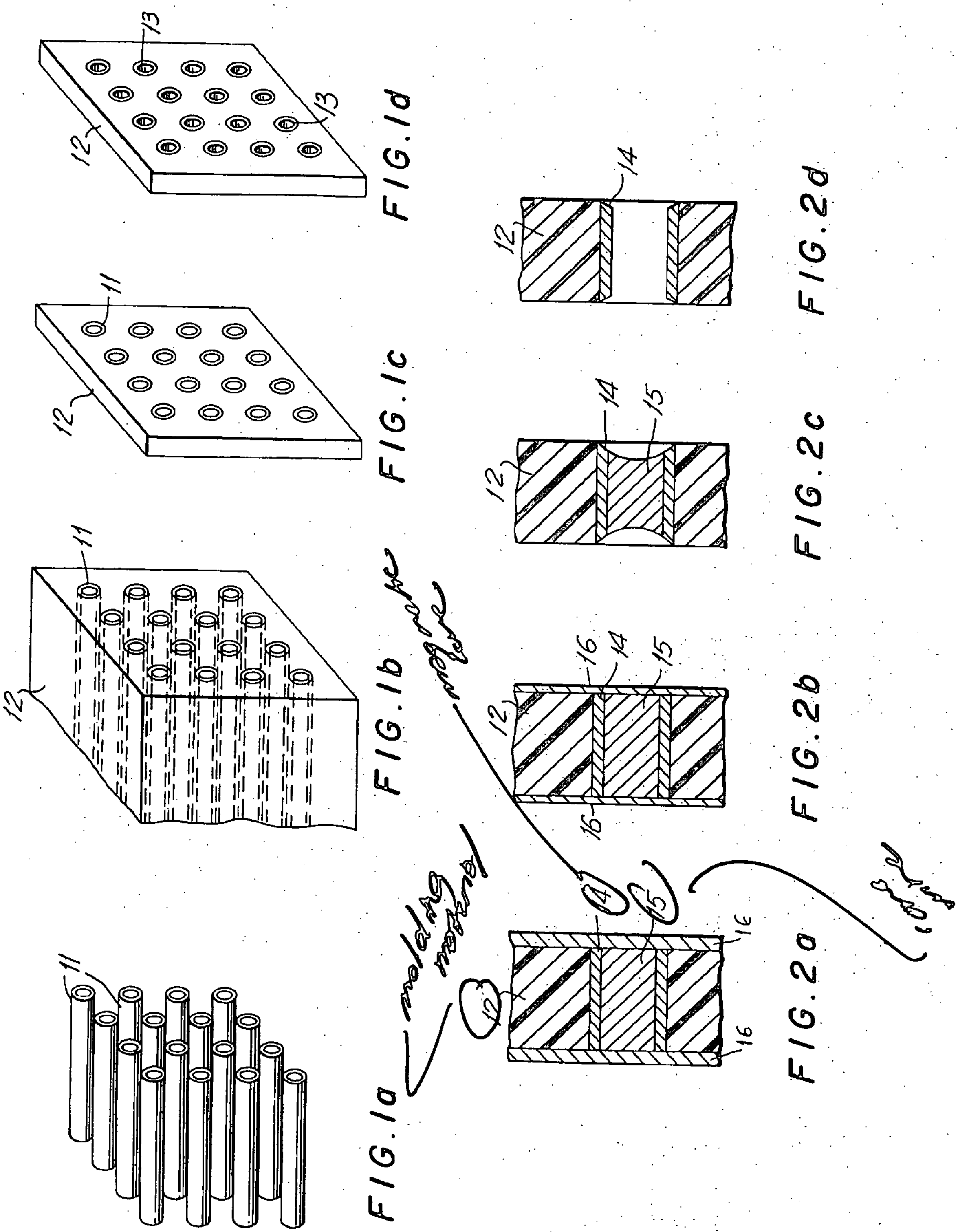
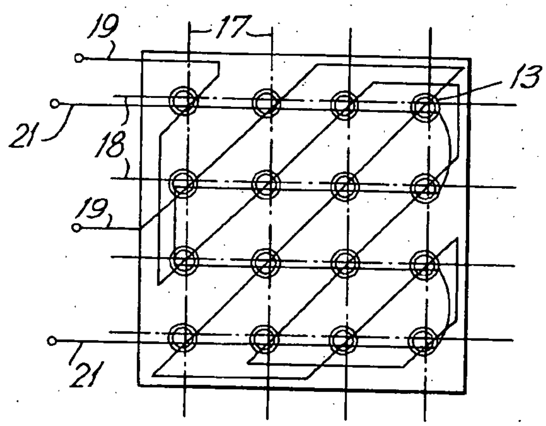


FIG. 1a FIG. 1b FIG. 1c FIG. 1d

FIG. 2a FIG. 2b FIG. 2c FIG. 2d

FIG.3



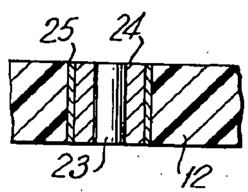


FIG.4

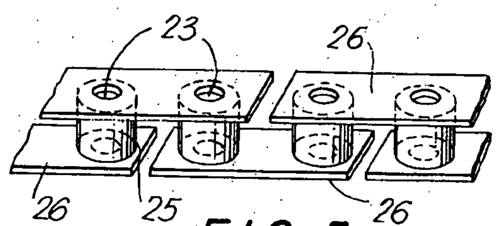


FIG.5

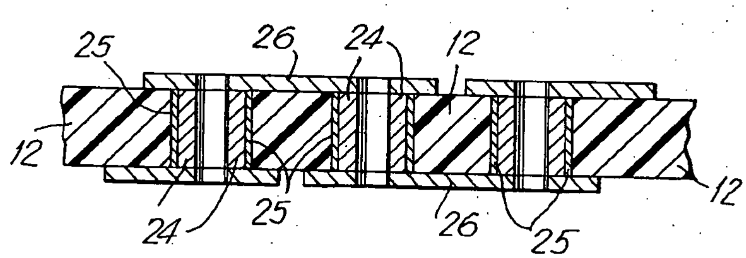


FIG.6

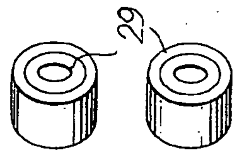


FIG. 7d

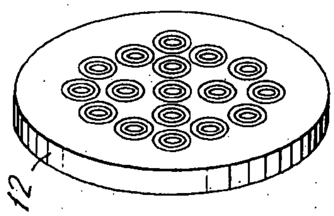


FIG. 7c

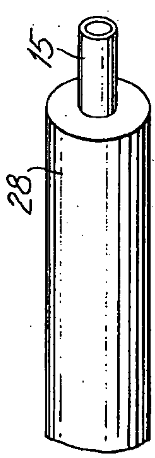


FIG. 7a

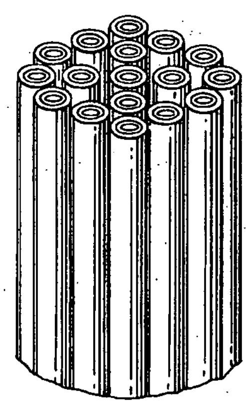


FIG. 7b

FIG. 8

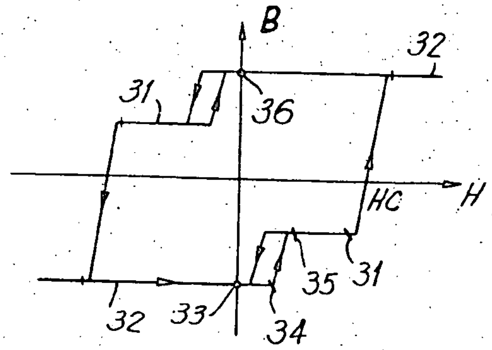


FIG. 9a

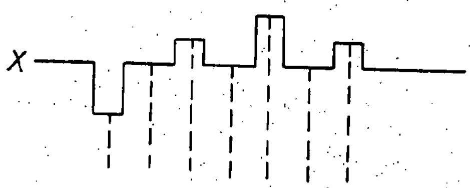


FIG. 9b

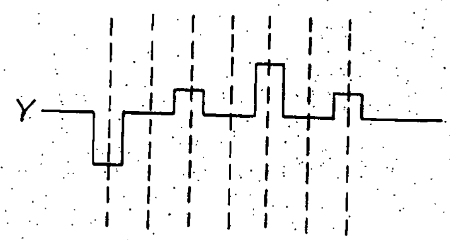
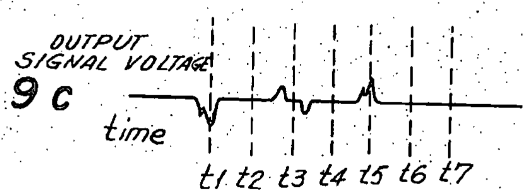


FIG. 9c



METHOD OF MANUFACTURE OF ANNULAR MAGNETIC CORES

This application is a Continuation-in Part of Pat. application Ser. No. 755,368, filed Aug. 26, 1968.

DESCRIPTION OF THE INVENTION

The invention relates to a method of manufacture of annular magnetic cores. More particularly, the invention relates to a method of manufacture of annular magnetic cores of very small size utilized in memory devices and the like.

Memory devices utilized in electronic computers and other equipment must be of high speed and of smaller size and greater reliability than those utilized in other types of equipment, as well as being operable by less electrical energy than in other types of equipment. In order to satisfy these requirements, research work is being done on the miniaturization of ferrite cores and the development of magnetic thin film memory elements. Ferrite cores permit an increase of capacity, since such cores are relativey inexpensive and may be operated by a current coincidence selection system. Thus, many ferrite cores are utilized as memory elements in electronic computers, and the like. Ferrite cores, however, have defects or disadvantages. Thus, for example, the switching velocity is relatively slow and the temperature characteristic is unsuitable. Furthermore, recent miniaturization of ferrite cores in an effort to increase the speed and to operate such cores with less electrical energy has created difficulties in their manufacture and winding.

Magnetic thin film memory elements have a high switching velocity or speed and an excellent temperature characteristic. It is difficult, however, to increase the capacity of thin film memory elements, since the magnetic circuits of such elements themselves generally become open magnetic circuits. Moreover, since magnetic thin film memory elements are operated by a word selection system, peripheral circuits, such as the driving circuit and the selecting circuit of the memory device, may become complicated and complex and the equipment becomes expensive when the capacity of the memory device is increased.

The principal object of the present invention is to provide a new and improved method of manufacture of annular magnetic cores.

An object of the present invention is to provide a method of manufacture of annular magnetic cores which produces magnetic cores which do not have the disadvantages or defects of known cores.

An object of the present invention is to provide a method of manufacture of annular magnetic cores which produce magnetic cores of small size which are operable by very little electrical energy.

An object of the present invention is to provide a method of manufacture of annular magnetic cores which produces magnetic cores which are operable by current coincidence selection.

An object of the present invention is to provide a method of manufacture of annular magnetic cores which produces magnetic cores having a high switching speed and an excellent temperature characteristic.

An object of the present invention is to provide a method of manufacture of annular magnetic cores which is effective, efficient and reliable.

In accordance with the present invention, a plurality of core wires each covered by a layer of magnetic material are positioned in a desired arrangement relative to each other. The arrangement of covered core wires is embedded in molding material. The molding material is hardened to firmly affix the covered core wires in their arranged position. A section of the molded arrangement of covered wires is removed at substantially right angles to the axes of the wires. Each of the core wires is then removed from the section and the layer of magnetic material of each is retained in the section.

The layer of magnetic material is a thin film. The layer of magnetic material may comprise a plurality of metallic magnetic materials of different coercive forces. The magnetic material comprises a metal and the molding material comprises one of a metal and resin.

The molding material may comprise a low fusing point metal and insulation is provided between the magnetic thin film cores and the molding material.

In another embodiment of the present invention, each of the plurality of core wires positioned in a desired arrangement relative to each other is covered by a layer of electrically conductive material and a layer of magnetic material covering the conductive material.

The core wires may comprise wires covered by a thin layer of metal magnetic material and expanded to a desired thickness.

Magnetic cores produced by the method of the present invention have the same compound magnetic characteristic as the piggy-back twister disclosed by W. A. Baker in Session 8 of "Proceedings of the 1964 Intermag Conference" of Apr. 6, 7, 8, 1964.

In accordance with the present invention, a cylindrical electrical conductor may now be affixed directly or via insulating layers between the layer of magnetic material and each core wire which said layer covers. The covered core wires are then positioned in matrix form and the electrical conductors of cylindrical configuration on the cores may be electrically interconnected, so that such conductors may be utilized as the driving wires or sensing wires of a memory device. This results in a simplification of the process of winding the core and in facilitating the manufacture of a memory device.

The magnetic thin film core produced by the method of the present invention is provided by forming a closed magnetic circuit on the core wire by utilizing a metal magnetic material. The switching speed may be increased by utilizing a magnetic thin film as the metal magnetic material.

In order that the present invention may be readily carried into effect, it will now be described with reference to the accompanying drawings, wherein:

FIGS. 1*a*, 1*b*, 1*c* and 1*d* are schematic perspective views illustrating the method of manufacture of the present invention;

FIGS. 2*a* and 2*b* are schematic views, partly in section, illustrating the removal and polishing of distortion layers of the magnetic cores produced by the method of the present invention;

FIGS. 2*c* and 2*d* are schematic views, partly in section, illustrating the removal of a core wire in accordance with the method of the present invention;

FIG. 3 is a schematic diagram of a core matrix of a memory device utilizing the magnetic cores produced by the method of the present invention;

FIG. 4 is a schematic view, partly in section, illustrating a magnetic core produced by another embodiment of the present invention, wherein an electrically conductive cylinder is included within said core;

FIG. 5 is a perspective schematic view illustrating the electrical interconnection of magnetic cores produced by the method related to FIG. 4;

FIG. 6 is a sectional view of the electrically connected magnetic cores of FIG. 5;

FIGS. 7*a*, 7*b*, 7*c* and 7*d* illustrate the method of manufacture of the present invention for manufacturing individual magnetic cores;

FIG. 8 is a graphical presentation of the B-H curve of a double magnetic thin film core of the present invention; and

FIGS. 9*a*, 9*b* and 9*c* are graphical presentations of the waveforms of the driving current and the output voltage when the double magnetic thin film core of the present invention is non-destructively read out.

As shown in FIG. 1*a*, each of a plurality of core wires 11 is covered by a layer of magnetic material and said core wires are positioned in a desired arrangement relative to each other. The layer of magnetic material may be applied to each core wire 11 by any suitable process. Thus, the layer of magnetic material may be provided on the core wire 11 by electroplating, chemical plating, evaporation, sputtering, or any suitable mechanical or other process. The core wire 11 may be either electrically conductive or electrically non-conductive.

The magnetic material is preferably applied as a thin film which is illustrated in greatly exaggerated dimension in the FIGS. for the purposes of illustration. The mechanical process for applying the magnetic material to the core wire 11 involves coating a magnetic metal material on the core wire and thinning the wire by drawing it until it reaches the desired diameter or thickness and the desired dimension of the magnetic thin film. The arrangement of core wires 11 covered by layers of magnetic material is that of a matrix, as shown in FIG. 1*a*, wherein said core wires are positioned in rows and columns in a manner whereby adjacent ones thereof are equidistantly spaced from each other and are parallel to each other.

In accordance with the present invention, as shown in FIG. 1*b*, the arrangement of covered core wires 11 is embedded in molding material 12 and the molding material is hardened, so that said covered core wires are firmly affixed in their arranged positions.

After the molding material has hardened, a section of the molded arrangement of covered wires 11 is removed by cutting at substantially right angles to the axes of said wires. The cut or removed section is shown in FIG. 1*c*, wherein the segments of core wires 11 covered by magnetic thin filsm are embedded in the molding material 12 in a matrix arrangement.

In accordance with the method of the present invention, each of the core wires is then removed from the section and the layer of magnetic material or the magnetic thin film of each is retained in the section. Thus, for example, the section shown in FIG. 1*c* is immersed in a solution which dissolves or electrolyzes the core wires embedded in said section, but which does not dissolve or electrolyze said magnetic thin films or the molding material 12. The core wires may also be dissolved by heat or pyrolysis. FIG. 1*d* shows the section after the core wires have been dissolved and only the magnetic thin films 13 remain in the molding material 12. The resultant device is thus a magnetic thin film core matrix, as shown in FIG. 1*d*.

Metal magnetic thin film cores may be manufactured by various methods, among which the mechanical method is of special advantage due to the facility of control of the characteristics of the cores and the rapidity of manufacture. When the magnetic thin film core is manufactured by the electroplating method, the core wires utilized are generally thin wires of copper or copper alloy such as, for example, beryllium copper or phosphor bronze. It is necessary to control the condition of the surface of the core wire, since it sensitively affects the magnetic characteristic of the electroplated end product.

A magnetic thin film core must have an excellent square type magnetic characteristic in the direction of the closed magnetic circuit thereof. Thus, in the manufacture of the magnetic thin film core, it is necessary to form an easy magnetization direction axis in the circumferential direction and to improve the sqare magnetic characteristic in the circumferential direction by electroplating during the application of a magnetic field in the circumferential direction of the core wire by producing a current flow in said core wire.

A magnetic thin film core may be distorted during the manufacturing process. If the magnetic thin film core is distorted, it causes deterioration of the magnetic characteristic of the core. It is thus desirable, during the manfuacture of the magnetic thin film core, that the magnetic distortion of the magnetic thin film be adjusted, so that the characteristic of said magnetic thin film core will not deteriorate.

Initially, before the magnetic thin film-covered core wires 11 are embedded in the molding material, they are provided at specific lengths, so that they may be tested for their magnetic characteristics and only those having desired characteristics may be utilized. The sections which are cut from the hardened molding material, as shown in FIGS. 1*c* and 1*d*, are cut at a specific thickness, so that the magnetic thin film cores have a specific length.

The molding material 12 must harden to a suitable degree and must not require such heat in hardening or generate such heat in hardening that the magnetic thin film cores will deteriorate or become distorted or deformed during such hardening or upon the completion of such hardening. A suitable molding material may comprise, for example, a thermoplastic or thermosetting resin or an alloy having a low fusing point. The alloy of low fusing point may comprise a metal. In such case, of course, insulation must be provided between the magnetic thin film cores and the molding material. When heat must be provided in the hardening process or heat is generated in the hardening process, and particularly when a metal of low fusing point is utilized as the molding material, the magnetic thin film cores must withstand such heat. The utilization of a metal as the molding material 12 has advantages which include the improvement of heat radiation in the magnetic thin film cores and driving wires, the decrease of the impedance of the X and Y driving wires and a reduction in noise induced in the sensing wires.

When the sections are cut from the hardened molding material 12, care must be taken to avoid distortion or deformation of the thin film magnetic material-covered core wires 11. Even if a covered core wire 11 is cut with care, distortion layers are formed in the cut

surfaces and cause deterioration in the magnetic characteristic. It is therefore desirable to remove the distortion layers. The distortion layers may generally be removed by mechanical polishing and electrolytic polishing, or by chemical polishing. FIGS. 2*a*, 2*b*, 2*c* and 2*d* disclose a method for removing the distortion layers.

Immediately after the removal of the section of hardened molding material, the cut surfaces of the covered core wires of the matrix are uneven and the cut surfaces of the molding material 12, the magnetic thin film core 14, as shown in FIGS. 2*a* to 2*d*, and the core wire 15, as shown in FIGS. 2*a* to 2*c*, have distortion layers 16, as shown in FIG. 2*a*. Most of the distortion layers 16 may be removed by mechanical polishing such as, for example, polishing with emery paper. It is then necessary to polish the distortion layers 16 with care, commencing with rough polishing and ending with fine polishing. Most of the distortion layers 16 may be removed by mechanical polishing, although some of said distortion layers remain, as shown in FIG. 2*b*.

Upon the completion of mechanical polishing, the distortion layers 16 are removed completely, as shown in FIG. 2*c*, by electrolytic polishing or chemical polishing. The core wire 15 is then removed or dissolved, as shown in FIGS. 2*c* and 2*d*, and the magnetic thin film core 14, as shown in FIG. 2*d*, having no distortion due to the cutting of the section, remains. The core wire 15 may comprise a metal, in which case it may be removed by chemical or electrolytic polishing. The core wire 15 may comprise an organic material such as, for example, a resin, in which case it may be removed by dissolution in a solvent or by pyrolysis. Thus, for example, when the core wire 15 comprises a copper alloy such as, for example, phosphor bronze or beryllium copper, or just copper, and the molding material 12 comprises a resin, said core wire may be removed by chemical polishing by a mixture of chromic acid having a concentration of 200 to 600 grams per liter and sulfuric acid having a concentration of 5 to 100 grams per liter.

After the core wire 15 (FIGS. 2*a*, 2*b* and 2*c*) has been removed, a protective film of electrically insulated material is applied to the inside of the magnetic thin film core 14 (FIGS. 2*a*, 2*b*, 2*c* and 2*d*), to protect said magnetic thin film core from distortion or damage during the winding of the driving wire and the sensing wire. A magnetic thin film core 14 manufactured in the foregoing manner may be utilized in the same manner as a ferrite core.

FIG. 3 illustrates a matrix comprising the magnetic thin film cores 13 (FIG. 1*d*) produced by the method of the present invention. In FIGS. 2*a* to 2*d*, the magnetic thin film 14 represents said magnetic thin film during the process of manufacture, whereas in FIG. 1*d*, the magnetic thin film 13 represents the completed magnetic thin film core after the completion of the method of manufacture. In FIG. 3, a plurality of magnetic thin film cores 13 are arranged in matrix form, in rows and columns. The X driving wires 17 are coupled to each of the magnetic thin film cores 13, as are the Y driving wires 18.

In FIG. 3, a sensing wire 19 is coupled to each of the magnetic thin film cores 13, as indicated, and an inhibit wire 21 is coupled to each of said cores. In the usual manner of operation of a core matrix, when there is current in the X and Y driving wires of a selected magnetic thin film core 13, said core, at the intersection of said driving wires, is read out. Read-in is provided at a magnetic thin film core 13 when there is current in the X and Y driving wires of said core as well as in the inhibit wire thereof.

A magnetic thin film core matrix may be formed of magnetic thin film cores 23, as shown in FIG. 4. The magnetic thin film core 23 comprises a different embodiment from the magnetic thin film cores 13 of FIG. 1*d*. In the embodiment of FIG. 4, the magnetic thin film core 23 comprises an electrical conductor 24 of cylindrical configuration which covers the core wire (not shown in FIG. 4). The magnetic thin film 25 covers the electrical conductor 24. The embodiment of FIG. 4 thus differs from that of FIG. 1*d* and FIG. 2*d* in that an electrical conductor is interposed between the core wire and the magnetic thin film.

The cylindrical conductors 24 of the magnetic thin film cores 23 may be electrically coupled to each other, as desired, by electrically conductlve film or layers 26, as shown in FIGS. 5 and 6. The electrical conductors 26 may be provided by evaporation, sputtering, chemical plating, or the like. The circuit comprising the cylindrical conductors 24 and the conductive films or layers 26 may be utilized, as shown in FIGS. 5 and 6, as a driving wire or as a sensing wire of a matrix arrangement. Furthermore, a two wire or four wire matrix may be provided by windings through the holes of the cylindrical conductors 24.

A cylindrical conductor such as, for example, the cylindrical conductor 24 of FIGS. 4 and 6, may be provided with a magnetic thin film by coating a conductive material such as, for example, gold, on the core wire prior to the step illustrated in FIG. 1*a* of the method of manufacture. The gold will not dissolve during the dissolution or removal of the core wire later In the method of manufacture. A magnetic thin film is then provided on the conductive material or gold and the covered core wires are then arranged in position, as shown in FIG. 1*a*. The method of manufacture then proceeds as described. Another method of providing a cylindrical conductor is to first provide a magnetic thin film core 13 (FIG. 1*d*) and then provide a film or layer of electrically conductive material on the inside cylindrical surface of the magnetic thin film by any suitable means such as, for example, plating, sputtering, evaporation, or the like. In the latter method, the magnetic characteristic of the magnetic thin film core may be improved by providing a layer or film of electrically insulating material on the inside cylindrical surface of the magnetic thin film prior to the application of a film or layer of electrically conductive material, so that the magnetic material and the electrically conductive material are insulated from each other.

The size of the magnetic thin film core produced by the method of the present invention is considerably smaller than the size of a conventional ferrite core. It is thus possible to manufacture a memory device by the method of the present invention in which there are considerably more memory units than usual, which memory units may be driven by very little electrical energy. A magnetic thin film core produced by the method of the present invention has a very high switching speed which may be provided by suitable adjustment of its magnetic characteristic, the configuration of the core and the thickness of the magnetic thin film. Furthermore, the driving wire and the sensing wire may be shortened in length by the increase in the number of memory units. The magnetic thin film cores produced

by the method of the present invention thus provides high speed read-out and read-in.

FIGS. 7a, 7b, 7c and 7d disclose a method of manufacture of an individual magnetic thin film core. The magnetic thin film is provided as a cover on the core wire 15 and a support layer 28 is provided on said magnetic thin film as shown in FIG. 7a, and a plurality of such covered core wires is provided in a group or bundle, as shown in FIGS. 7b. The bundle of covered core wires is molded together by the molding material 12, as shown in FIG. 7c, and a section of the hardened molding material containing the covered core wires is cut or removed at right angles to the axes of said core wires. Both the core wires 15 and the molding material 12 are then removed or dissolved, so that a plurality of individual magnetic thin film cores 29, covered with support material are provided, as shown in FIG. 7d. The support layers 28 of the magnetic thin film cores 29 function to protect the magnetic thin films from deformation or distortion and may comprise any suitable support material. The magnetic thin film cores 29 may be utilized in exactly the same manner as ferrite cores.

Memory units having many characteristics may be provided by the magnetic thin film cores produced by the method of the present invention by providing the layer of magnetic material as a plurality of metallic magnetic materials of different coercive forces. Thus, a plurality of magnetic thin films are provided as covers on the core wire, one upon another to form a plurality of magnetic thin film layers. Thus, for example, a double magnetic thin film may be provided by covering the core with a magnetic thin film of relatively small coercive force Hc, henceforth referred to as a soft film, and covering the soft film with a magnetic thin film of relative large coercive force Hc, henceforth referred to as a hard film. The hard film is provided directly over the soft film and the magnetic characteristics and thicknesses of the soft film and the hard film are adjusted. Suitable adjustment of the magnetic characteristics and thicknesses of the soft film and the hard film permits the provision of a magnetic coupling directly between said soft film and said hard film and provides a B-H curve having a compound magnetic characteristic, as shown in FIG. 8. If the double magnetic thin film cores are arranged in a grid or matrix of which both axes are at right angles to each other, a double magnetic thin film matrix is provided which provides non-destructive read-out. FIG. 9a discloses the X driving current waveform. FIG. 9b discloses the Y driving current waveform. FIG. 9c discloses the output voltage waveform. FIGS. 9a, 9b and 9c illustrate the non-destructive read-out and read-in of the double magnetic thin film core matrix.

If a signal 1 is read-in at a time t1, the magnitudes of the driving current in the X and Y wires are selected so that they may generate magnetic fields which are smaller in intensity than the magnitudes 31 of the B-H curve of FIG. 8, and the sum of the driving current in the X and Y wires may generate a magnetic field having an intensity greater than the magnitude 32 of said curve. As a result, magnetization of the soft film and of the hard film is inverted at the time t1 and such magnetizations are stabilized at the point 33 of the B-H curve of FIG. 8, in the time interval between t2 and t3. The signal 1 is read out at the time t3. In such case, the magnitudes of the driving current in the X and Y wires are selected so that such currents may generate magnetic fields which are lower in intensity than the magnitude 34 of the B-H curve of FIG. 8 and the sum of said currents may generate a magnetic field which is higher in intensity than the magnitude 35 of said B-H curve and smaller in intensity than the magnitude 31 of said B-H curve. The inversion of magnetization therefore occurs only in the soft film at the time t3 and an output voltage is provided in the sensing wire.

At the time t4, the soft film is stabilized in the direction of magnetization of the hard film by direct magnetic coupling and is returned to the point 33 of the B-H curve of FIG. 8. Thus, the information or signal 1 is not destroyed by the read-out and may be read out at any time. The information or signal 0 is read in at the time t5 when there is current in each of the X and Y wires, in the same manner as the read-in of the information or signal 1, and is stabilized at a point 36 of the B-H curve of FIG. 8 at the time t6. Read-out at the time t7 does not cause inversion of the magnetization and an output voltage is not provided since a magnetic field is applied in the direction in which the soft film and the hard film are saturated. Furthermore, the change of magnetization does not occur.

In the aforedescribed manner, the double magnetic thin film core provides non-destructive readout as well as high speed memory units which may be driven by very little electrical energy. These advantages are attained by suitable adjustment of the magnetic characteristic and configuration of the magnetic thin films.

As hereinbefore described, and in accordance with the present invention, the method of the present invention produces an extremely thin magnetic film core and permits such core to be utilized as a memory unit in considerable numbers in a memory device, which memory unit functions to switch at very high speeds and may be driven by very little electrical energy or low voltage. The method of manufacture of the present invention may also be utilized for the manufacture of metal magnetic cores in general.

As hereinbefore described, in the thin film magnetic cores of the invention, plated thin films or plated wire memories, for example, are utilized as the memory elements. The thickness of the films of these thin film magnetic cores is thus less than several microns and the diameter of each core wire is about 0.1 mm.

A high speed memory may be constructed utilizing the aforedescribed magnetic wire memories due to the property of the magnetic films, but in such a high speed memory, magnetic films are formed continuously on the magnetic wires, so that mutual magnetic interference occurs between adjacent portions of magnetic wires. This prevents the arbitrary shortening of the interval between the portions.

For the aforedescribed reasons, a memory of a high bit density and of high speed may be constructed by separating the thin films from each other in the form of cores, just as such cores are separated from each other in a core memory. This is one of the considerations which went into the development of the present invention. In accordance with the invention, the magnetic wires are molded so that the substrate for holding the thin film cores, which have a final thickness of less than several microns and an inner diameter of approximately 0.1 mm, may be formed by molding. Thus, numerous cores may be produced in quantity by cutting the magnetic wires after the molding material has hardened. This results in cores forming a memory element

group of good order with uniform intervals between the memory units, and with a high density.

When a low fusing point metal is used as the molding material, the metal, through which the magnetic flux cannot pass easily, may reduce the noises in the memory and may radiate heat very effectively.

Magnetic wires may be manufactured at a relatively higher speed compared with the method of using plated wires. The device for manufacturing the magnetic wires may be simplified and the distortions produced in the cutting of the magnetic wires may be decreased. The manufacture of plated wires involves the problem that in the manufacture of magnetic films of a thickness of several microns it is absolutely necessary to dip the core wires in the plating liquid for a long period of time due to the current value of the core wires and the electrolyzing action of the plating liquid. This results in a limitation on the core wire winding speed. In the manufacture of the plated wires, furthermore, the manufacturing equipment becomes complicated because the aforedescribed core wire winding speed must be properly controlled and the current value and concentration of the plating liquid must be kept constant. In the method of the invention, wherein the wires are expanded, the wires may be wound at an arbitrary high speed, so far as no distortion is produced in the expanded wires. A high speed winding may thus be reached.

Furthermore, the core wires of the plated wires must be of conductive material which is generally soft. In the expanding of the wires it is not necessary to consider the conductivity of the wires and only the hardness must be considered. A material slightly harder than the magnetic material is best suited for the expanding process. The cut surface of the magnetic wire utilizing the core wire slightly higher than the magnetic material may be made clean and less distortion is produced in the magnetic wire. Less distortion insures better magnetic characteristics, and magnetic thin film cores having less distortion compared to plated wires may be provided so that the variation of the width of the magnetic films by the succeeding distortion eliminating operation may be made small. That is, the precision of the width may be increased, and this results in the facilitation of the manufacture.

While the invention has been described by means of specific examples and in specific embodiments, we do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

We claim:

1. A method of manufacture of annular thin magnetic cores, comprising the steps of

positioning a plurality of core wires each covered by a layer of electrically conductive material with the layer of electrically conductive material covered by a thin layer of magnetic material in a desired arrangement relative to each other;

embedding the arrangement of covered core wires in molding material;

hardening the molding material to firmly affix the covered core wires in their arranged positions;

cutting a section of the molded arrangement of covered wires at substantially right angles to the axes of said wires;

removing distortion layers of the cut surfaces of the section of the molded arrangement of covered wires;

removing each of the core wires from said section and retaining the layer of electrically conductive material and the layer of magnetic material of each in said section; and

electrically coupling the layers of electrically conductive material to each other.

2. A method as claimed in claim 1, wherein the layer of magnetic material comprises a plurality of metallic magnetic materials of different coercive forces.

3. A method as claimed in claim 1, wherein the magnetic material comprises a metal and the molding material comprises one of a metal and a resin.

4. A method as claimed in claim 1, wherein the distortion layers are removed by mechanical positioning.

5. A method as claimed in claim 1, wherein the distortion layers are removed by chemical polishing.

6. A method as claimed in claim 1, wherein the molding material is a low fusing point metal and insulation is provided between the magnetic thin film cores and the molding material.

7. A method as claimed in claim 1, wherein the core wires comprise wires covered by a thin layer of metal magnetic material and expanded to a desired thickness.

* * * * *